POLISHING APPARATUS

BACKGROUND OF THE INVENTION

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Field of the Invention:

The present invention relates to a polishing apparatus, and more particularly to a polishing apparatus for polishing a workpiece such as a semiconductor wafer to a flat mirror finish.

Description of the Related Art:

Recent rapid progress in semiconductor device integration demands smaller and smaller wiring patterns or interconnections and also narrower spaces between interconnections which connect active areas. One of the processes available for forming such interconnection is photolithography. Though the photolithographic process can form interconnections that are at most 0.5 μm wide, it requires that surfaces on which pattern images are to be focused by a stepper be as flat as possible because the depth of focus of the optical system is relatively small.

It is therefore necessary to make the surfaces of semiconductor wafers flat for photolithography. One customary way of flattening the surfaces of semiconductor wafers is to polish them by a chemical mechanical polishing (CMP). The chemical mechanical polishing is performed by pressing a semiconductor wafer held by a carrier against a polishing cloth mounted on a turntable while supplying an abrasive liquid containing abrasive grains or material onto the polishing cloth.

For polishing a compound semiconductor or the like, two different abrasive liquids are supplied in two stages to polish the compound semiconductor. For example, U.S. patent No. 4,141,180 and Japanese laid-open patent publication No. 4-334025 disclose polishing apparatuses for polishing a compound semiconductor, respectively. Each of the disclosed polishing apparatuses has two turntables. A carrier which holds a semiconductor wafer is moved between the turntables, for polishing the semiconductor wafer by means of a two-stage polishing comprising a primary polishing and a secondary polishing on the respective turntables and cleaning the semiconductor wafer between the two-stage polishing. In the cleaning process, the lower surface, which has been polished, of the semiconductor wafer is cleaned by water and/or a brush.

The conventional polishing apparatuses have suffered the following problems:

(1) Since the cleaning process which is carried out between the primary polishing and the secondary polishing is effected in such a state that the semiconductor wafer is being attached to the carrier, upper and side surfaces of the semiconductor wafer cannot be cleaned. The abrasive liquid containing abrasive grains which has been used in the primary polishing and remained on the upper and side surfaces of the semiconductor wafer serves as a pollution source in the secondary polishing, thus lowering quality of the polished semiconductor wafer.

(2) In the polishing apparatus disclosed in U.S. patent No. 4,141,180, since the two turntables are positioned

closely to each other, the abrasive liquid on one of the turntables reaches the other of the turntables and tends to contaminate the semiconductor wafer when it is polished on the other of the turntable.

(3) Some workpieces such as silicon wafers are not required to be polished in the two-stage polishing. Since the polishing apparatus has only a single carrier in U.S. patent No. 4,141,180, both the turntables cannot be simultaneously operated for increasing the throughput of the workpieces that can be processed by the polishing apparatus. The polishing apparatus disclosed in Japanese laid-open patent publication No. 4-334025 has two carriers that move on the same rail between two of the turntables and the cleaning unit. Even if one of the carriers finishes a polishing operation, it has to wait until the other carrier finishes its polishing operation. Therefore, the efficiency of operation of the carriers is relatively low, adversely affecting the throughput and the quality of semiconductor wafers which have been polished.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a polishing apparatus which can improve quality and yield of workpieces by preventing the workpiece from being contaminated with an abrasive liquid used in a previous polishing process in a multi-stage polishing such as a two-stage polishing, and can polish workpieces simultaneously to increase throughput of the workpieces in a single-stage polishing.

According to the present invention, there is provided a polishing apparatus comprising storage means for storing workpieces to be polished; polishing means including at least two polishing units each having a turntable with a polishing cloth mounted thereon and a top ring for supporting a workpiece and pressing the workpiece against the polishing cloth; cleaning means for cleaning the workpiece which has been polished by either one of the polishing units, in such a state that the workpiece is removed from the top ring; and transfer means for transferring the workpiece between two of the storage means, the polishing means and the cleaning means.

The polishing apparatus may further comprise reversing means for reversing a workpiece before or after the workpiece is polished by either one of the polishing units. The cleaning means may comprise at least two cleaning units, and the reversing means may comprise at least two reversing units. The polishing units may be spaced from the storage means comprising a storage cassette in confronting relation thereto, and at least one of the cleaning units may be disposed on each side of a transfer line extending between the polishing units and the storage cassette. The polishing units may be spaced from the storage means comprising a storage cassette in confronting relation thereto, and at least one of the reversing units may be disposed on each side of a transfer line extending between the polishing units and the storage cassette.

According to the present invention, there is also provided a polishing apparatus comprising at least one storage cassette for storing workpieces to be polished; at least two

polishing units each having a turntable with a polishing cloth mounted thereon and a top ring for supporting a workpiece and pressing the workpiece against the polishing cloth; at least one cleaning unit for cleaning the workpiece which has been polished by either one of the polishing units; and a transfer device for transferring the workpiece between two of the storage cassette, the polishing units and the cleaning unit.

The above and other objects, features, and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic plan view of a polishing apparatus according to a first embodiment of the present invention;

FIG. 2 is a perspective view of the polishing apparatus shown in FIG. 1;

FIG. 3 is a vertical cross-sectional view of a polishing unit in the polishing apparatus according to the first embodiment of the present invention;

FIGS. 4A and 4B are schematic plan views illustrative of different modes of operation of the polishing apparatus shown in FIG. 1; and

FIG. 5 is a schematic plan view of a polishing apparatus according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A first embodiment of the present invention will be described below with reference to FIGS. 1 through 3.

As shown in FIGS. 1 and 2, a polishing apparatus comprises a pair of polishing units 1a, 1b positioned at one end of a rectangular floor space and spaced from each other in confronting relation to each other, and a pair of loading/unloading units positioned at the other end of the rectangular floor space and having respective wafer storage cassettes 2a, 2b spaced from the polishing units 1a, 1b in confronting relation thereto. Two transfer robots 4a, 4b are movably mounted on a rail 3 which extends between the polishing units 1a, 1b and the loading/unloading units, thereby providing a transfer line along the rail 3. The polishing apparatus also has a pair of reversing units 5, 6 disposed one on each side of the transfer line and two pairs of cleaning units 7a, 7b and 8a, 8b disposed one pair on each side of the transfer line. The reversing unit 5 is positioned between the cleaning units 7a and 8a, and the reversing unit 6 is positioned between the cleaning units 7b and 8b. Each of the reversing units 5, 6 serves to turn a semiconductor wafer over.

The polishing units 1a and 1b are of basically the same specifications, and are located symmetrically with respect to the transfer line. Each of the polishing units 1a, 1b comprises a turntable 9 with a polishing cloth attached to an upper surface thereof, a top ring head 10 for holding a semiconductor wafer under vacuum and pressing the semiconductor wafer against the polishing cloth on the upper surface of the

turntable 9, and a dressing head 11 for dressing the polishing cloth.

FIG. 3 shows a detailed structure of the polishing unit 1a or 1b.

As shown in FIG. 3, the top ring head 10 has a top ring 13 positioned above the turntable 9 for holding a semiconductor wafer 20 and pressing the semiconductor wafer 20 against the turntable 9. The top ring 13 is located in an off-center position with respect to the turntable 9. The turntable 9 is rotatable about its own axis as indicated by the arrow A by a motor (not shown) which is coupled through a shaft 9a to the turntable 9. A polishing cloth 14 is attached to an upper surface of the turntable 9.

The top ring 13 is coupled to a motor (not shown) and also to a lifting/lowering cylinder (not shown). The top ring 13 is vertically movable and rotatable about its own axis as indicated by the arrows B, C by the motor and the lifting/lowering cylinder. The top ring 13 can therefore press the semiconductor wafer 20 against the polishing cloth 14 under a desired pressure. The semiconductor wafer 20 is attached to a lower surface of the top ring 13 under a vacuum or the like. A guide ring 16 is mounted on the outer circumferential edge of the lower surface of the top ring 13 for preventing the semiconductor wafer 20 from being disengaged from the top ring 13.

An abrasive liquid supply nozzle 15 is disposed above the turntable 9 for supplying an abrasive liquid containing abrasive grains onto the polishing cloth 14 attached to the

turntable 9. A frame 17 is disposed around the turntable 9 for collecting the abrasive liquid and water which are discharged from the turntable 9. The frame 17 has a gutter 17a formed at a lower portion thereof for draining the abrasive liquid and water that has been discharged from the turntable 9.

The dressing head 11 has a dressing member 18 for dressing the polishing cloth 14. The dressing member 18 is positioned above the turntable 9 in diametrically opposite relation to the top ring 13. The polishing cloth 14 is supplied with a dressing liquid such as water from a dressing liquid supply nozzle 21 extending over the turntable 9. The dressing member 18 is coupled to a motor (not shown) and also to a lifting/lowering cylinder (not shown). The dressing member 18 is vertically movable and rotatable about its own axis as indicated by the arrows D, E by the motor and the lifting/lowering cylinder.

The dressing member 18 is of a disk shape and holds a dressing element 19 on its lower surface. The lower surface of the dressing member 18, to which the dressing element 19 is attached, has holes (not shown) defined therein which are connected to a vacuum source for attaching the dressing element 19 under vacuum to the lower surface of the dressing member 18.

As shown in FIG. 1, each of the polishing units 1a, 1b also has a pusher 12 positioned near the transfer line 3 for transferring a semiconductor wafer 20 to and receiving a semiconductor wafer 20 from the top ring 13. The top ring 13 is swingable in a horizontal plane, and the pusher 12 is vertically movable.

The polishing unit 1a or 1b operates as follows:

The semiconductor wafer 20 is held on the lower surface of the top ring 13, and pressed against the polishing cloth 14 on the upper surface of the turntable 9. The turntable 9 and the top ring 13 are rotated relatively to each other for thereby bringing the lower surface of the semiconductor wafer 20 in sliding contact with the polishing cloth 14. At this time, the abrasive liquid nozzle 15 supplies the abrasive liquid to the polishing cloth 14. The lower surface of the semiconductor wafer 20 is now polished by a combination of a mechanical polishing action of abrasive grains in the abrasive liquid and a chemical polishing action of an alkaline solution in the abrasive liquid. The abrasive liquid which has been applied to polish the semiconductor wafer 20 is scattered outwardly off the turntable 9 into the frame 17 under centrifugal forces caused by the rotation of the turntable 9, and collected by the gutter 17a in the lower portion of the frame 17. The polishing process comes to an end when the semiconductor wafer 20 is polished by a predetermined thickness of a surface layer thereof. When the polishing process is finished, the polishing properties of the polishing cloth 14 is changed and the polishing performance of the polishing cloth 14 deteriorates. Therefore, the polishing cloth 14 is dressed to restore its polishing properties.

The polishing cloth 14 is dressed as follows:

While the dressing member 18 with the dressing element 19 held on its lower surface and the turntable 9 are being rotated, the dressing element 19 is pressed against the

polishing cloth 14 to apply a predetermined pressure to the polishing cloth 14. At the same time that or before the dressing element 19 contacts the polishing cloth 14, a dressing liquid such as water is supplied from the dressing liquid supply nozzle 21 to the upper surface of the polishing cloth 14. The dressing liquid is supplied for the purposes of discharging an abrasive liquid and ground-off particles of the semiconductor wafer which remain on the polishing cloth 14 and removing frictional heat that is generated by the engagement between the dressing element 19 and the polishing cloth 14. The dressing liquid supplied to the polishing cloth 14 is then scattered outwardly off the turntable 9 into the frame 17 under centrifugal forces caused by the rotation of the turntable 9, and collected by the gutter 17a of the frame 17.

ENS A27 The cleaning units 7a, 7b and 8a, 8b may be of any desired types. For example, the cleaning units 7a, 7b which are positioned near the polishing units 1a, 1b may be of the type which scrubs both sides, i.e., face and reverse sides, of a semiconductor wafer with rollers having respective sponge layers, and the cleaning units 8a, 8b which are positioned near the wafer storage cassettes 2a, 2b may be of the type which supplies a cleaning solution to a semiconductor wafer that is being held at its edge and rotated in a horizontal plane. Each of the cleaning units 8a, 8b also serves as a drying unit for spin-drying a semiconductor wafer under centrifugal forces until it is dried. The cleaning units 7a, 7b can perform a primary cleaning of the semiconductor wafer, and the cleaning units 8a, 8b can perform a secondary cleaning of the

semiconductor wafer which has been subjected to the primary cleaning.

Each of the transfer robots 4a, 4b has an articulated arm mounted on a carriage which is movable along the rail 3. The articulated arm is bendable in a horizontal plane. The articulated arm has, on each of upper and lower portions thereof, two grippers that can act as dry and wet fingers. The transfer robot 4a operates to cover a region ranging from the reversing units 5, 6 to the storage cassettes 2a, 2b, and the transfer robot 4b operates to cover a region ranging from the reversing units 5, 6 to the polishing units 1a, 1b.

The reversing units 5, 6 are required in the illustrated embodiment because of the storage cassettes 2a, 2b which store semiconductor wafers with their surfaces, which are to be polished or have been polished, facing upwardly. However, the reversing units 5, 6 may be dispensed with if semiconductor wafers are stored in the storage cassettes 2a, 2b with their surfaces, which are to be polished or have been polished, facing downwardly, and alternatively if the transfer robots 4a, 4b have a mechanism for reversing semiconductor wafers. In the illustrated embodiment, the reversing unit 5 serves to reverse a dry semiconductor wafer, and the reversing unit 6 serves to reverse a wet semiconductor wafer.

The polishing apparatus can be operated selectively in a series mode of polishing operation (hereinafter referred to as a serial processing) as shown in FIG. 4A and a parallel mode of polishing operation (hereinafter referred to as a parallel processing) as shown in FIG. 4B. The serial and

parallel processings will be described below.

FIGS. 4A and 4B show the states of the semiconductor wafers in respective positions; shows the position in which the semiconductor wafers are in the state of their surfaces, which are to be polished or have been polished, facing upwardly; ● shows the position in which the semiconductor wafers are in the state of their surfaces, which are to be polished or have been polished, facing downwardly; shows the position in which the semiconductor wafers are in the state of their surfaces, which have been reversed and are to be polished, facing downwardly; and shows the position in which the semiconductor wafers are in the state of their surfaces, which have been polished and reversed, facing upwardly.

(1) Serial processing (FIG. 4A):

In the serial processing, a semiconductor wafer is polished by means of a two-stage polishing, and three out of the four cleaning units 7a, 7b, 8b are operated to clean semiconductor wafers.

B5 A3 As shown by solid lines, a semiconductor wafer is transferred from the storage cassette 2a to the reversing unit 5. The semiconductor wafer is then transferred from the reversing unit 5 to the first polishing unit 1a after reversed in the reversing unit 5. The semiconductor wafer is polished in the first polishing unit 1a and transferred therefrom to the cleaning unit 7a where it is cleaned. The cleaned semiconductor wafer is then transferred from the cleaning unit 7a to the second polishing unit 1b where it is polished. The

semiconductor wafer is then transferred from the second polishing unit 1b to the cleaning unit 7b where it is cleaned. The cleaned semiconductor wafer is then transferred from the cleaning unit 7b to the reversing unit 6. The semiconductor wafer is then transferred from the reversing unit 6 to the cleaning unit 8b after reversed in the reversing unit 6. The semiconductor wafer is then transferred from the cleaning unit 8b to the storage cassette 2a after cleaned and dried in the cleaning unit 8b. The transfer robots 4a, 4b use the respective dry fingers when handling dry semiconductor wafers, and the respective wet fingers when handling wet semiconductor wafers. The pusher 12 of the polishing unit 1a receives the semiconductor wafer to be polished from the transfer robot 4b, is elevated and transfers the semiconductor wafer to the top ring 13 when the top ring 13 is positioned above the pusher 12. The semiconductor wafer which has been polished is rinsed by a rinsing liquid supplied from a rinsing liquid supply device which is provided at the pusher 12.

INS A47 After the semiconductor wafer is applied to a primary polishing in the polishing unit 1a, the semiconductor wafer is removed from the top ring 13 of the polishing unit 1a, and rinsed at the position of the pusher 12, and then cleaned in the cleaning unit 7a. Therefore, any abrasive liquid containing abrasive grains adhering to the polished surface, the reverse side of the polished surface, and side edge of the semiconductor wafer due to the primary polishing in the polishing unit 1a is completely removed. Then, the semiconductor wafer is applied to a secondary polishing in the

polishing unit 1b, and then cleaned by the primary cleaning process of the cleaning unit 7b and the secondary cleaning process of the cleaning unit 8b. Thereafter, the polished and cleaned semiconductor wafer is spin-dried and returned to the storage cassette 2a. In the serial processing, polishing conditions of the primary polishing and secondary polishing are different from each other.

(2) Parallel processing (FIG. 4B):

Dss A5 In the parallel processing, a semiconductor wafer is polished in a single polishing process. Two semiconductor wafers are simultaneously polished, and all the four cleaning units 7a, 7b, 8a, 8b are operated to clean semiconductor wafers. One or both of the storage cassettes 2a, 2b may be used. In the illustrated embodiment, only the storage cassette 2a is used, and there are two routes in which semiconductor wafers are processed.

Dss A6 In one of the routes, as shown by solid lines, a semiconductor wafer is transferred from the storage cassette 2a to the reversing unit 5. The semiconductor wafer is then transferred from the reversing unit 5 to the polishing unit 1a after reversed in the reversing unit 5. The semiconductor wafer is polished in the polishing unit 1a and transferred therefrom to the cleaning unit 7a where it is cleaned. The cleaned semiconductor wafer is then transferred from the cleaning unit 7a to the reversing unit 6. The semiconductor wafer is then transferred from the reversing unit 6 to the cleaning unit 8a after reversed in the reversing unit 6. Thereafter, the semiconductor wafer is transferred from the

cleaning unit 8a to the storage cassette 2a after cleaned and dried in the cleaning unit 8a.

Ins A7 In the other of the routes, as shown by broken lines, another semiconductor wafer is transferred from the storage cassette 2a to the reversing unit 5. The semiconductor wafer is then transferred from the reversing unit 5 to the polishing unit 1b after reversed in the reversing unit 5. The semiconductor wafer is polished in the polishing unit 1b and transferred therefrom to the cleaning unit 7b where it is cleaned. The cleaned semiconductor wafer is then transferred from the cleaning unit 7b to the reversing unit 6. The semiconductor wafer is then transferred from the reversing unit 6 to the cleaning unit 8b after reversed in the reversing unit 6. Thereafter, the semiconductor wafer is cleaned and dried in the cleaning unit 8b, and transferred to the storage cassette 2a. The transfer robots 4a, 4b use the respective dry fingers when handling dry semiconductor wafers, and the respective wet fingers when handling wet semiconductor wafers. The reversing units 5 handles a dry semiconductor wafer, and the reversing unit 6 handles a wet semiconductor wafer in the same way as the serial processing. In the above parallel processing, the primary cleaning process is preformed by the cleaning units 7a, 7b, and the secondary cleaning process is preformed by the cleaning units 8a, 8b. For cleaning a semiconductor wafer, either one of the cleaning units 7a, 7b and either one of the cleaning units 8a, 8b may be used. In the parallel processing, polishing conditions in the polishing units 1a, 1b may be the same, cleaning conditions in the cleaning units 7a, 7b may be

the same, and cleaning conditions in the cleaning units 8a, 8b may be the same.

FIG. 5 schematically shows in plan a polishing apparatus according to a second embodiment of the present invention. The polishing apparatus according to the second embodiment differs from the polishing apparatus according to the first embodiment in that the transfer robots 4a, 4b do not move on a rail, but are fixedly installed in position. The polishing apparatus shown in FIG. 5 is suitable for use in applications where semiconductor wafers are not required to be transferred in a long distance, and is simpler in structure than the polishing apparatus shown in FIG. 1. In this embodiment, the transfer line also extends between the polishing units and the storage cassettes.

The number of cleaning units, the number of transfer robots, and the layout of these cleaning units and transfer robots may be modified. For example, if the polishing apparatus is not operated in the parallel processing, then the polishing apparatus needs only three cleaning units. Whether the reversing units are to be used, the number, layout, and type of reversing units, the type of transfer robots, and whether the pushers are to be used may also be selected or changed as desired.

Example:

Semiconductor wafers were actually polished by the polishing apparatus according to the present invention. In the serial processing, the abrasive liquid applied by the polishing unit 1a was not carried over to the polishing unit 1b, thus

causing no contamination to the semiconductor wafers.

The wafer processing efficiencies, i.e., the throughputs (the number of processed wafers/hour) of a comparative polishing apparatus and the inventive polishing apparatus in both the serial and parallel processings are shown in Table given below:

Table

TT: turntable

	Throughputs (the number of processed wafers/hour)		
	1TT comparative	2TT serial	2TT parallel
processing time (seconds) per one wafer (1st TT / 2nd TT)	120/-	120/60	120/120
1TT(comparative)	19		
2TT(serial processing)		19	
2TT(parallel processing)			38

The comparative polishing apparatus employed one turntable, a required number of cleaning units, a required number of reversing units, and a required number of transfer robots. In serial and parallel processings, two turntables and two top rings are employed. As can be seen from Table above, the inventive polishing apparatus in the parallel processing has a throughput per turntable which is comparable to that of the comparative polishing apparatus. Therefore, the inventive polishing apparatus in the parallel processing has a greatly increased wafer processing capability per floor space.

Sub A8 As is apparent from the above description, according to the present invention, the polishing apparatus can improve

quality and yield of workpieces by preventing the workpiece from being contaminated with an abrasive liquid used in a previous polishing process in a multi-stage polishing such as a two-stage polishing, and can polish workpieces simultaneously to increase throughput of the workpieces in a single-stage polishing.

Further, according to the present invention, a serial processing in which a two-stage polishing is performed and a parallel processing in which a single-stage polishing is performed can be freely selected.

In the embodiments, although the top ring handles only one semiconductor wafer, the top ring may handle a plurality of semiconductor wafers simultaneously. A plurality of top rings may be provided in each polishing unit.

Although certain preferred embodiments of the present invention have been shown and described in detail, it should be understood that various changes and modifications may be made therein without departing from the scope of the appended claims.